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RESEARCH MEMORANDUM

INVESTIGATION OF A MISSILE AIRFRAME WITH CONTROL SURFACES CONSISTING OF PROJECTING QUADRANTS OF THE NOSE CONE

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

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RESEARCH MEMORANDUM

INVESTIGATION OF A MISSILE AIRFRAME WITH CONTROL SURFACES CONSISTING OF PROJECTING QUADRANTS OF THE NOSE CONE

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SUMMARY

The results of an investigation of a model simulating a missile with extensible control surfaces and small-span fins are presented. Normal-force, axial-force, and pitching-moment coefficients based on body cross-sectional area and diameter are given for various control deflections up to a maximum of 30°. Sufficient information is presented to permit an evaluation of the maneuvering performance of the airframe at supersonic Mach numbers up to 3. The importance of body lift is illustrated by the fact that as the Mach number increases, the airframe turning performance compares more and more favorably with that of an equivalent body fitted with variable-incidence wings.

A comparison between Newtonian impact theory and experiment indicates that the theory predicts, with reasonable accuracy, the incremental force and moment coefficients due to control-surface deflection at the higher Mach numbers.

INTRODUCTION

One problem associated with air-to-air guided missiles is that of increased airplane drag due to externally mounted missiles or the large airplane volume needed to store the weapons internally. This problem, of course, is the result of the large size of the missile body needed to house electronic components and the span of the wings usually considered necessary to give the lift required for adequate maneuvering, particularly at high altitudes and low velocities. The need for large-size bodies may be reduced by advances in electronic design. The need for large-span wings to produce lift is also subject to some question, especially at high Mach numbers, and it is the purpose of the present report to study this matter.

It is suggested that a suitable lift-producing device may be a control that is flush with the body except when in operation. In order to determine the feasibility of such a control, an investigation of one type of missile airframe suitable for internal storage in an airplane was initiated. The investigation was conducted at Mach numbers of 1.2 and 1.9 in the Ames 6- by 6-foot supersonic wind tunnel and was extended to a Mach number of 2.94 in the Ames 1- by 3-foot supersonic wind tunnel. The results obtained in both facilities are reported herein.

SYMBOLS

The data are presented in the form of standard NACA coefficients as follows:

C_c — axial-force coefficient, $\frac{\text{axial force}}{qS}$

C_m — pitching-moment coefficient about a point 56.4 percent of the body length aft of the nose, $\frac{\text{pitching moment}}{qSd}$

C_N — normal-force coefficient, $\frac{\text{normal force}}{qS}$

C_{m_α} — rate of change of pitching-moment coefficient with change in angle of attack, $\frac{dC_m}{d\alpha}$

ΔC_c — incremental axial-force coefficient due to control-surface deflection

ΔC_m — incremental pitching-moment coefficient due to control-surface deflection

ΔC_N — incremental normal-force coefficient due to control-surface deflection

d — body diameter, ft

M — free-stream Mach number

q — free-stream dynamic pressure, lb/sq ft

R_e — Reynolds number based on body diameter

S — cross-sectional area of body, ft^2

α — angle of attack of longitudinal center line of body, deg

δ angle of deflection of control surface measured with respect to the surface of the nose cone, deg

APPARATUS, MODELS, AND TEST PROCEDURE

The experimental investigation at Mach numbers of 1.2 and 1.9 was conducted in the Ames 6- by 6-foot supersonic wind tunnel. In this wind tunnel, the Mach number can be varied continuously and the stagnation pressure can be regulated to maintain a given test Reynolds number. A description of the wind tunnel and its stream characteristics is given in detail in reference 1.

The test at a Mach number of 2.94 was performed in the Ames 1- by 3-foot supersonic wind tunnel No. 2 which is an intermittent-operation, nonreturn, variable-pressure wind tunnel with a maximum Mach number of 3.8. The nozzle of this tunnel is equipped with flexible top and bottom plates to provide the nozzle contour adjustment necessary for varying the Mach number.

The model consisted of a cylindrical body with a conical nose of cone angle 15.8° giving an over-all fineness ratio of 16. The control surface consisted of a quadrant of the cone. Eight low-aspect-ratio triangular-shape fins were mounted on the rear end of the body. These fins were constructed of constant thickness flat plate with leading edges rounded.

In the 6- by 6-foot wind tunnel, the model was mounted on the end of a cantilever sting support so constructed that the model was pitched in the horizontal plane of the tunnel without changing its axial position in the test section. A sting-type support system was also used in the 1- by 3-foot wind tunnel. However, this support system utilizes an arrangement which allows the model to be pitched in the vertical plane of the tunnel about a point in the center of the test section. The models were mounted on bent stings in both wind tunnels in order to increase the positive angle-of-attack range.

A photograph of the model is shown in figure 1. A dimensional sketch of the 6- by 6-foot wind-tunnel model is presented in figure 2. The model investigated in the 1- by 3-foot wind tunnel was a 1/3-scale representation of the 6- by 6-foot wind-tunnel model.

The normal forces, axial forces, and pitching moments on the 6- by 6-foot wind-tunnel model were measured by means of an electrical strain-gage balance contained within the body of the model. Each force and moment was measured by an individual strain gage. The strain-gage beams were housed within the balance case. The loads were transmitted to the

various strain-gage beams by a system of shafts and bearings which reduces both friction and interaction to a negligible amount.

Electrical strain gages were also used to measure the forces and moments on the 1- by 3-foot wind-tunnel model. The force gages were contained in a balance housing which was part of the sting support system; whereas the pitching-moment gage was mounted on the sting and utilized the sting as a strain-gage beam.

The investigation at Mach numbers of 1.2 and 1.9 was made at a Reynolds number of 0.77 million with a stagnation pressure of 8 and 9 pounds per square inch absolute, respectively. A constant Reynolds number of 0.91 million was maintained at a Mach number of 2.94 with a stagnation pressure of 50 pounds per square inch absolute.

REDUCTION OF DATA

The test data have been reduced to standard NACA coefficient form. Factors which could affect the accuracy of these data, and the corrections applied, are discussed in the following paragraphs.

Angle of Attack

In the 6- by 6-foot wind tunnel, the determination of the true angle of attack of the model under load required that corrections, as determined from static load deflection calibrations, be applied to the measured angle. In the 1- by 3-foot wind tunnel, schlieren photographs with a superimposed grid were used to determine the true angle of attack.

Stream Variations

Stream irregularities exist in both the 6- by 6-foot and 1- by 3-foot wind tunnels. A survey of the 6- by 6-foot wind tunnel at supersonic speeds (ref. 1) has shown the presence of some stream-angle variations in vertical planes but little in horizontal planes. To minimize the effects of these stream irregularities, the model was pitched in the horizontal plane of the tunnel where the most favorable flow conditions exist. A variation in static pressure along the tunnel caused the model to experience a buoyant force in the chordwise direction. Corrections for this buoyancy were applied to the axial-force data obtained from the 6- by 6-foot wind tunnel. Stream-angle variations in the 1- by 3-foot wind tunnel were determined by survey prior to the present

investigation. The irregularities of this type are believed to be within the accuracy of measurement of the angle of attack. Although a static pressure variation exists in the 1- by 3-foot wind tunnel, no buoyancy correction was necessary since the net effect on the model was negligible.

PRECISION

The following table lists the estimated uncertainties in the measurements, exclusive of the effects of stream-angle variations:

Quantity	Accuracy	
	M = 1.2, 1.9	M = 2.94
C_c	±0.01	±0.01
C_m	±.02	±.02
C_N	±.04	±.04
M	±.01	±.01
Re	$\pm .03 \times 10^6$	$\pm .03 \times 10^6$
α	±.1	±.2

RESULTS AND DISCUSSION

The results of the investigation in the form of normal-force, pitching-moment, and axial-force coefficients are given in figures 3, 4, 5, and 6. A study of these data shows several interesting aerodynamic phenomena. For example, the pitching-moment effectiveness of the control surface with the tail either on or off (figs. 3 and 4) is approximately independent of Mach number at angles of attack near zero and increases with Mach number at the highest angles ($\alpha \gtrsim 16^\circ$). This characteristic coupled with the marked increase in the value of the parameter C_{m_α} with increasing Mach number (fig. 3) results in a rapid increase of the maximum trimmed lift with Mach number for the tail-on configuration (see fig. 5). Thus, the airframe should have improved maneuvering characteristics at high Mach numbers. On the other hand, it must be considered detrimental to this configuration that the axial force accompanying control-surface deflection is generally quite high (fig. 6). Finally, it is observed that the airframe is quite stable at low Mach numbers and the control surface is capable of developing only small normal accelerations. This characteristic may aid in reducing launching errors, but it also limits the maneuverability at low Mach numbers.

In order to obtain some idea of the relative maneuvering characteristics of the airframe, the trim normal-force coefficients attainable with a control-surface deflection of 15° (obtained by interpolation of the data of fig. 5) are plotted in figure 7 and compared with unpublished data obtained with the same basic body fitted with variable-incidence wings. The maximum incidence of the variable-incidence wings is limited by physical interference of adjacent wing panels to 15°. At $M = 2.94$ the comparison is based on an extrapolation of the data of figure 5(c). For these conditions, the comparison indicates that as the Mach number increases, the present airframe compares more and more favorably with the variable-incidence-wing airframe. Evidently, then, the requirement of large wing span tends to disappear with increasing Mach number. In any case, however, the advantages and disadvantages of the present airframe cannot be fully assessed until further investigations are made. The induced rolling moments may, for example, be significant and the general dynamic behavior of the airframe as a part of a missile system needs study.

As a final point, it is natural to inquire if there is a method of predicting the aerodynamic characteristics of the projecting control. For high-supersonic-speed application the Newtonian impact theory is suggested. For low-aspect-ratio shapes the theory may be applicable at somewhat lower speeds. Therefore, inasmuch as the control surface of the present airframe was a low-aspect-ratio segment of a body of revolution, Newtonian theory (ref. 2) was used to determine the incremental force and moment coefficients due to control-surface deflection. These theoretical results are compared with experimental values for the tail-off configuration in figure 8.[1] As may be seen, the Newtonian impact theory predicts these incremental forces and moments with from fair to reasonable accuracy, the agreement between theory and experiment improving, as would be expected, with increasing Mach number.

CONCLUSIONS

A brief analysis of the results of this investigation reveals the following:

1. The present airframe has adequate static stability in pitch and provides reasonable lift throughout the Mach number range investigated.

2. As the Mach number increases, the turning performance of the present airframe compares more and more favorably with that of an airframe with an equivalent body fitted with variable-incidence wings.

[1]The tail-on configuration is not treated here because the theory is inadequate for predicting flow approaching the fins.

3. Newtonian theory predicts, with reasonable accuracy, incremental force and moment coefficients due to control-surface deflection at higher Mach numbers.

Ames Aeronautical Laboratory
National Advisory Committee for Aeronautics
Moffett Field, Calif., Dec. 21, 1953

REFERENCES

1. Frick, Charles W., and Olson, Robert N.: Flow Studies in the Asymmetric Adjustable Nozzle of the Ames 6- by 6-Foot Supersonic Wind Tunnel. NACA RM A9E24, 1949.

2. Grimminger, G., Williams, E. P., and Young, G. B. W.: Lift on Inclined Bodies of Revolution in Hypersonic Flow. Jour. Aero. Sci., vol. 17, no. 11, Nov. 1950, pp. 675-690.

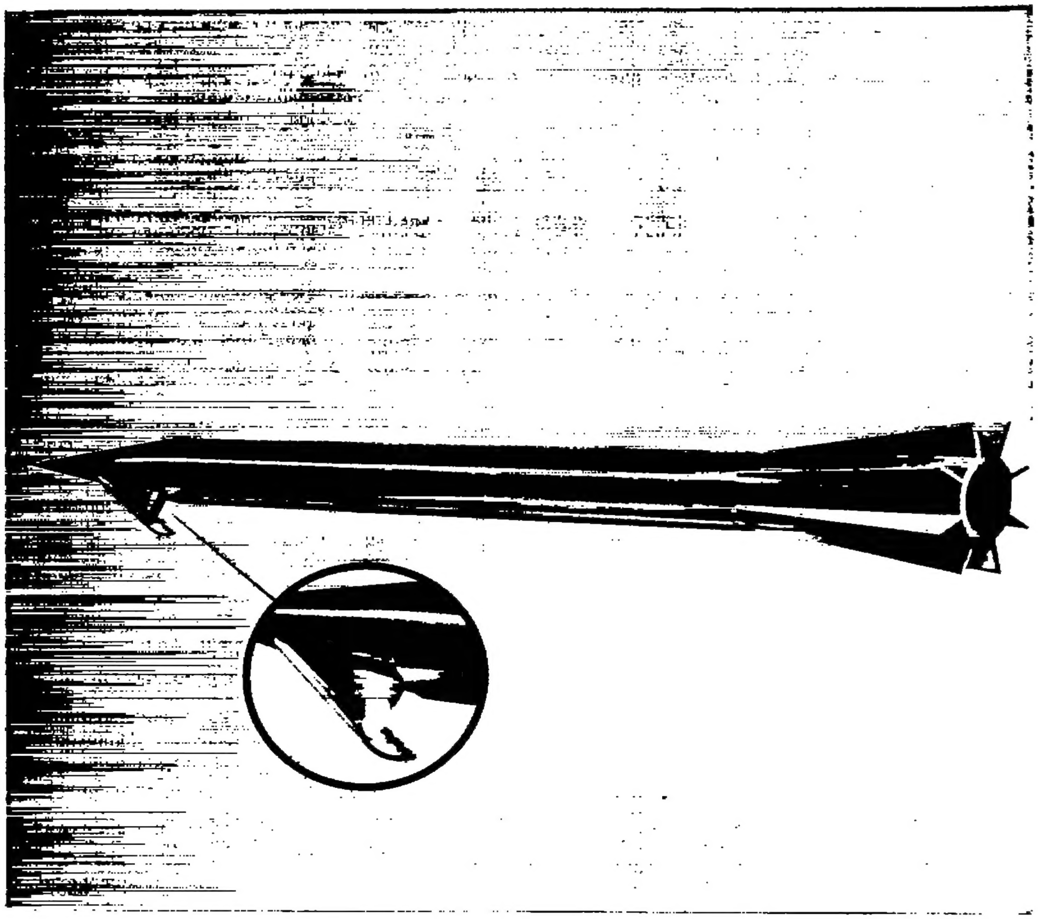

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Figure 1.- Photograph of the model.

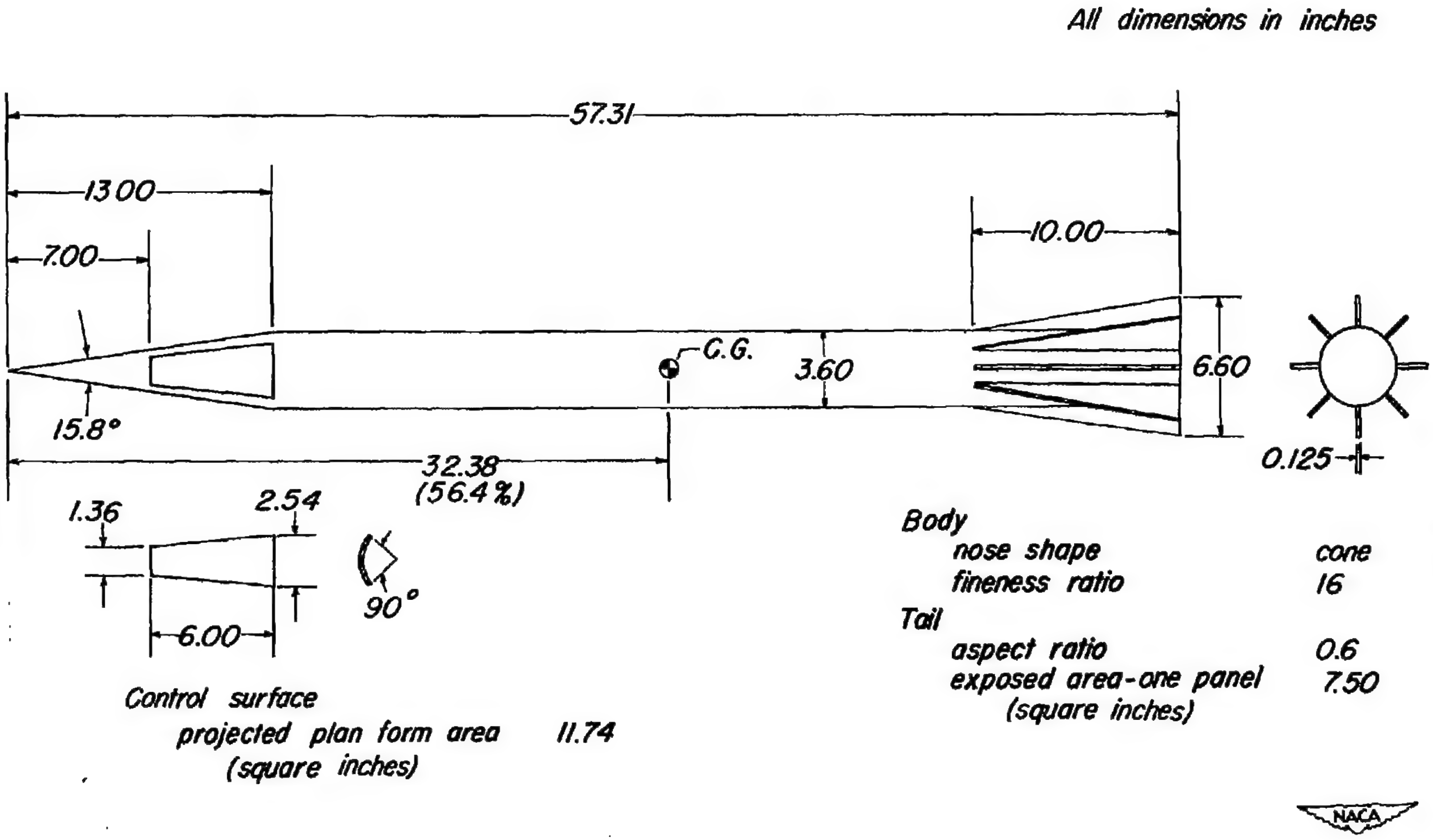
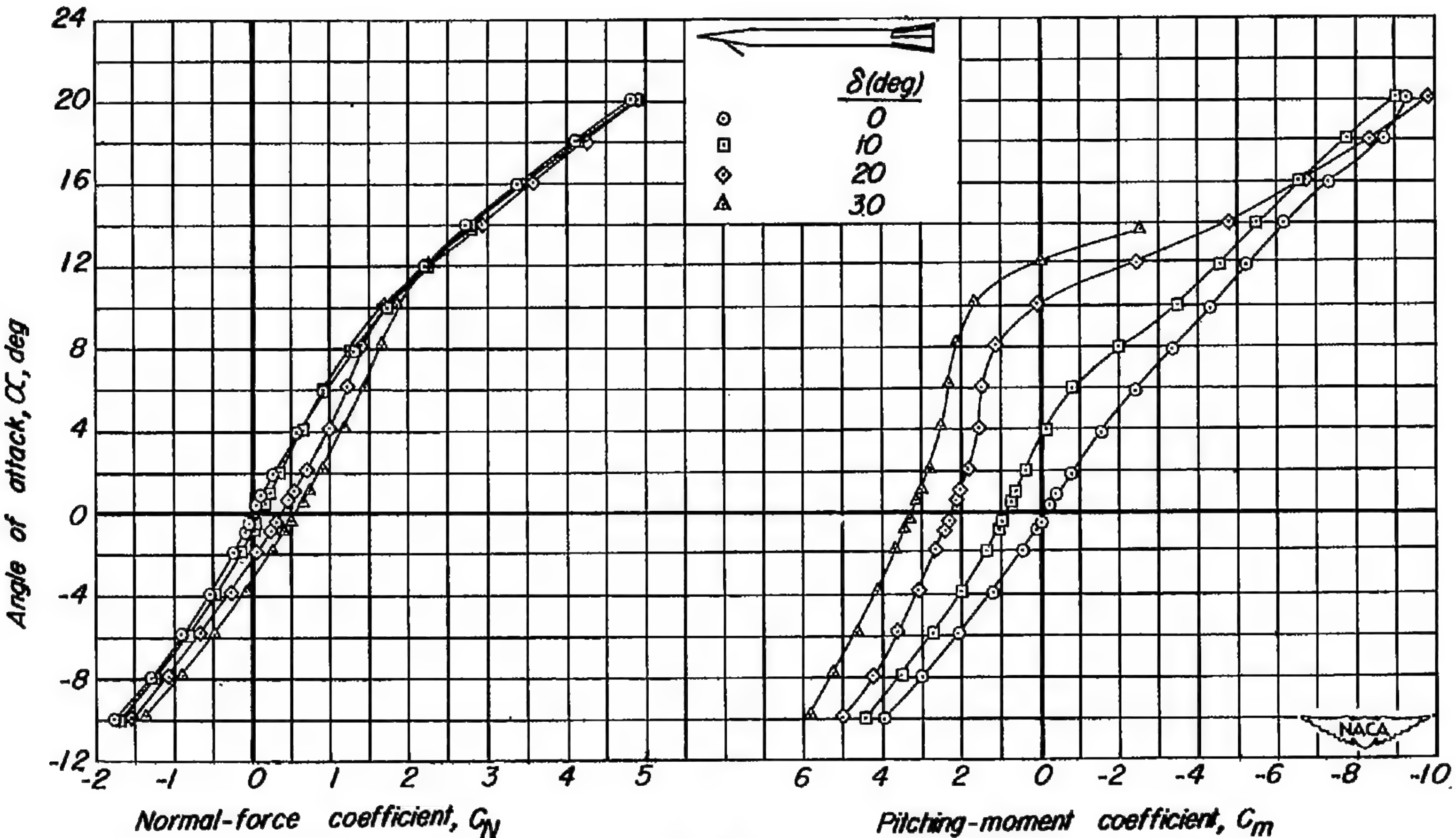
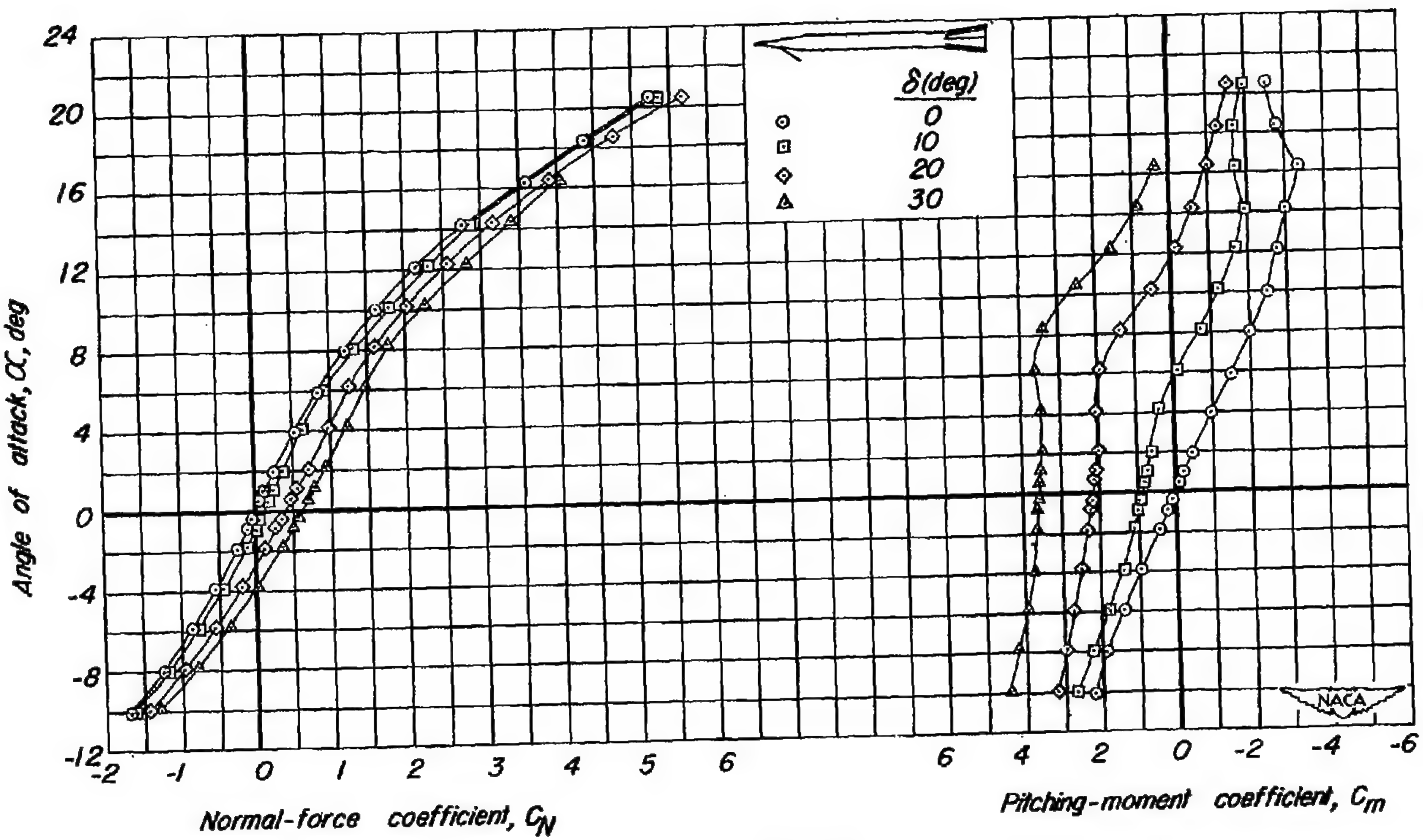


Figure 2.– Geometric characteristics of 6-by 6-foot wind-tunnel model.



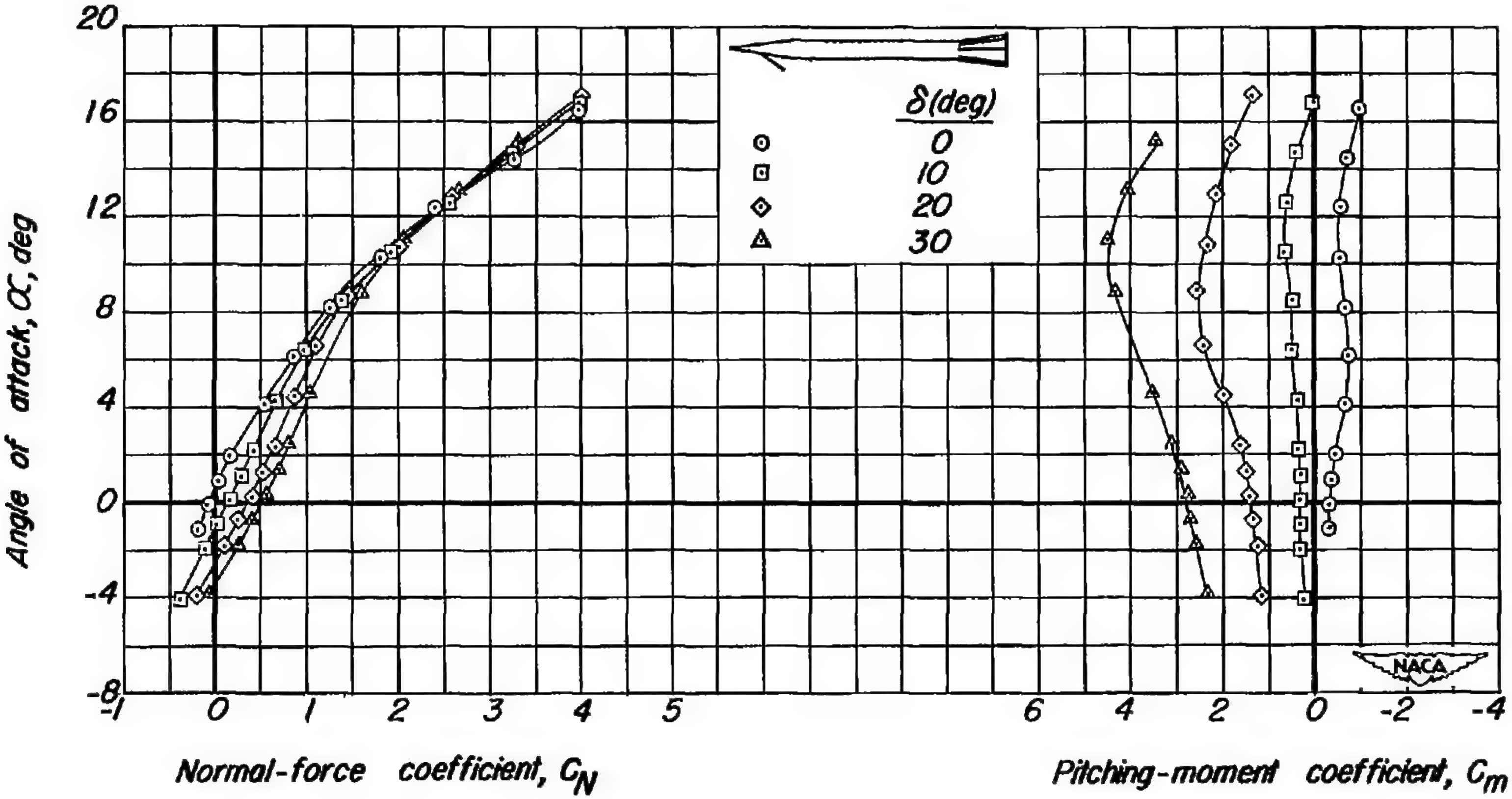
(a) M=1.2

Figure 3.- Normal-force and pitching-moment characteristics of the tail-on configuration for various control deflections, δ.



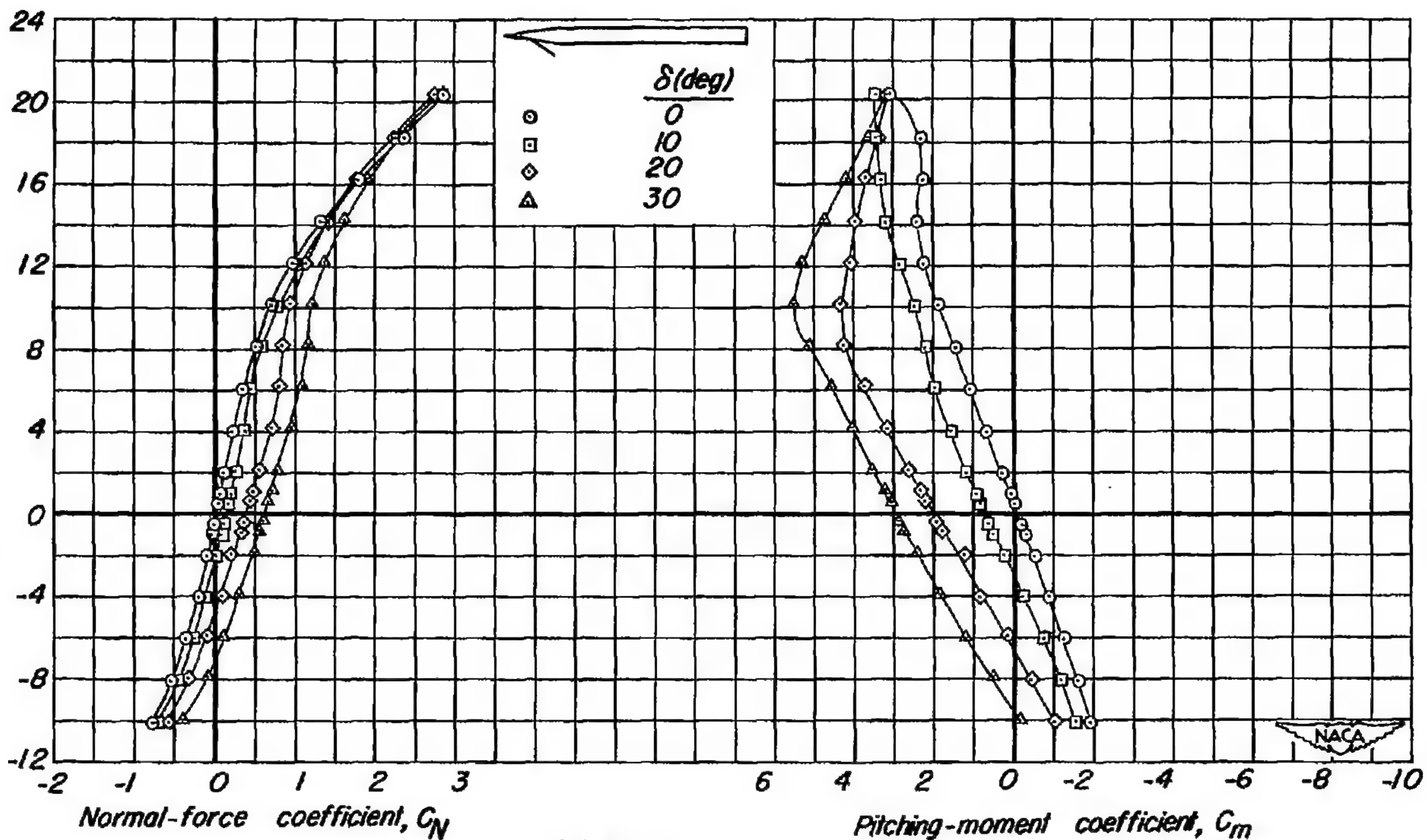
(b) M=1.9

Figure 3.- Continued.



(c) M=2.94

Figure 3.- Concluded.



(a) M=1.2

Figure 4.- Normal-force and pitching-moment characteristics of the tail-off configuration for various control deflections, δ.

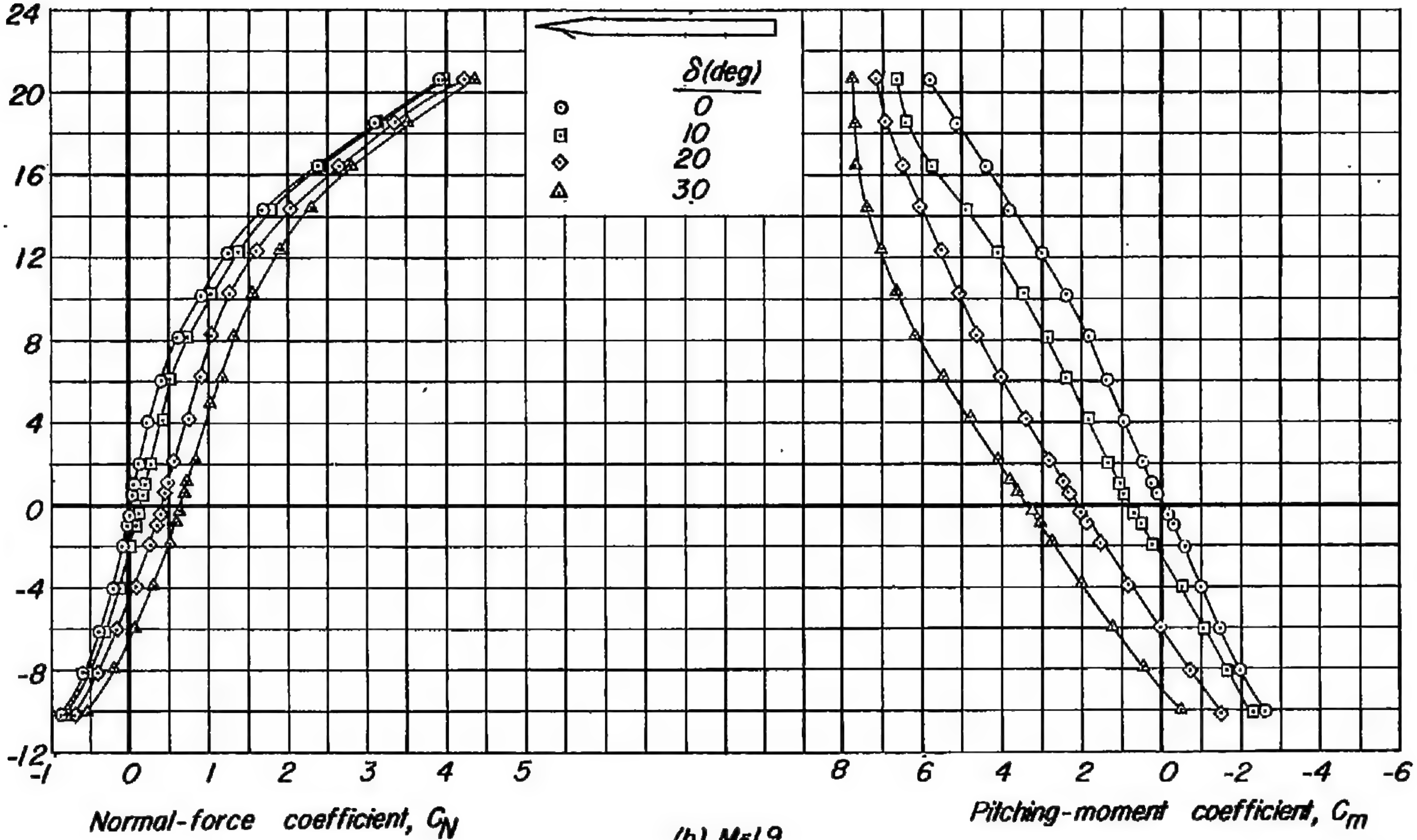
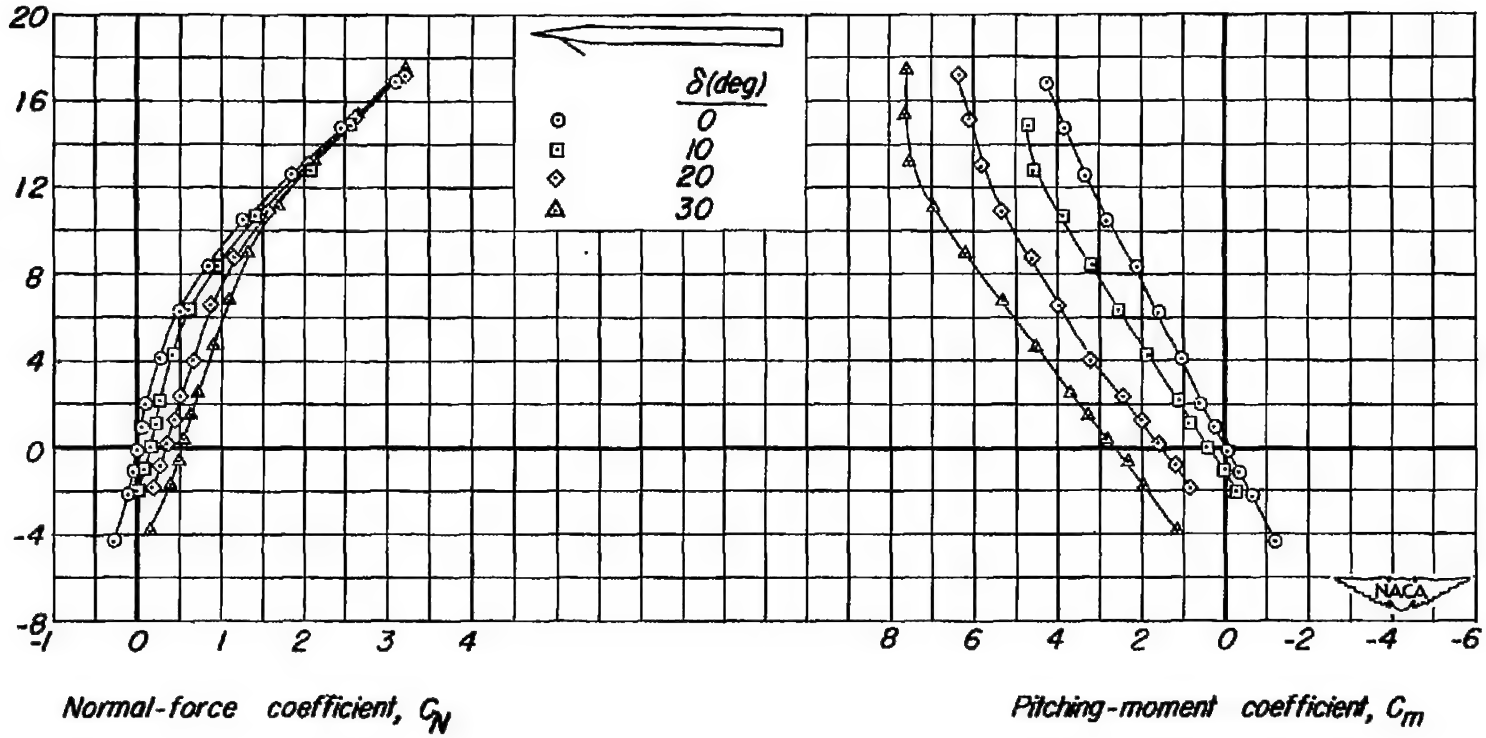
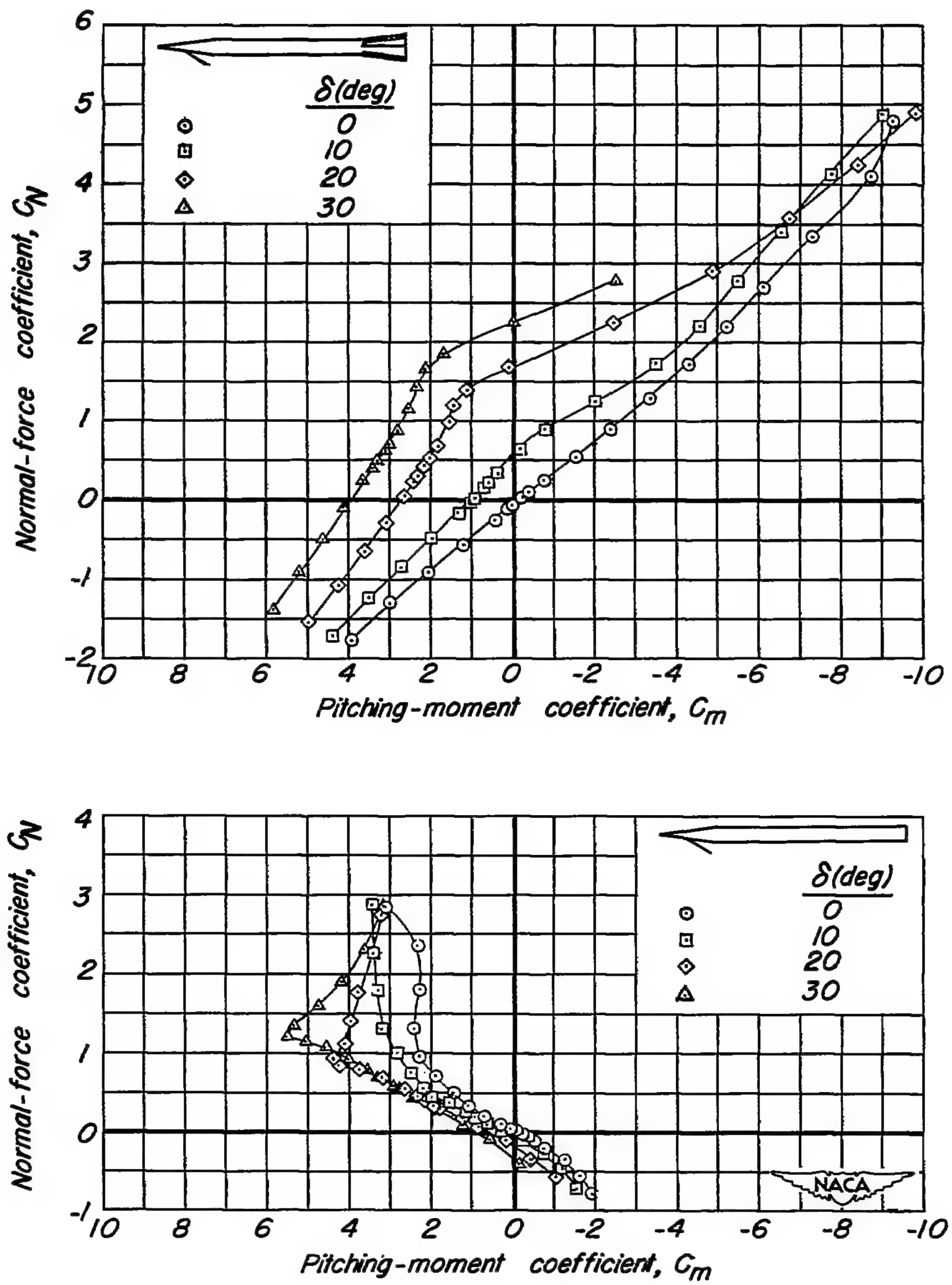


Figure 4.- Continued.



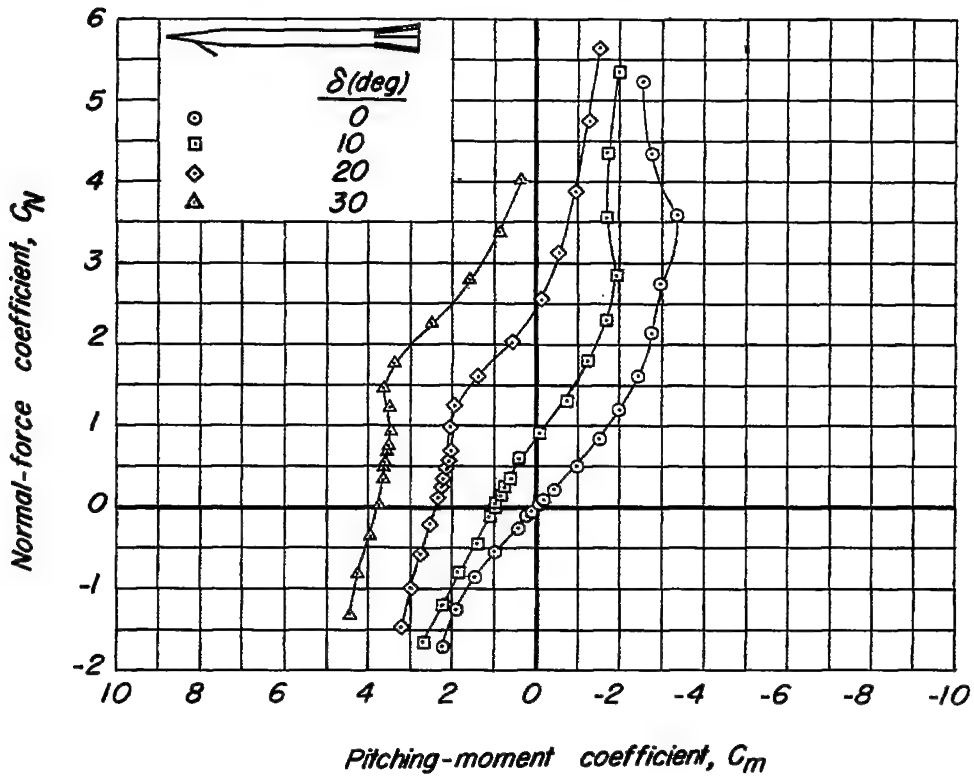
(c) M=2.94

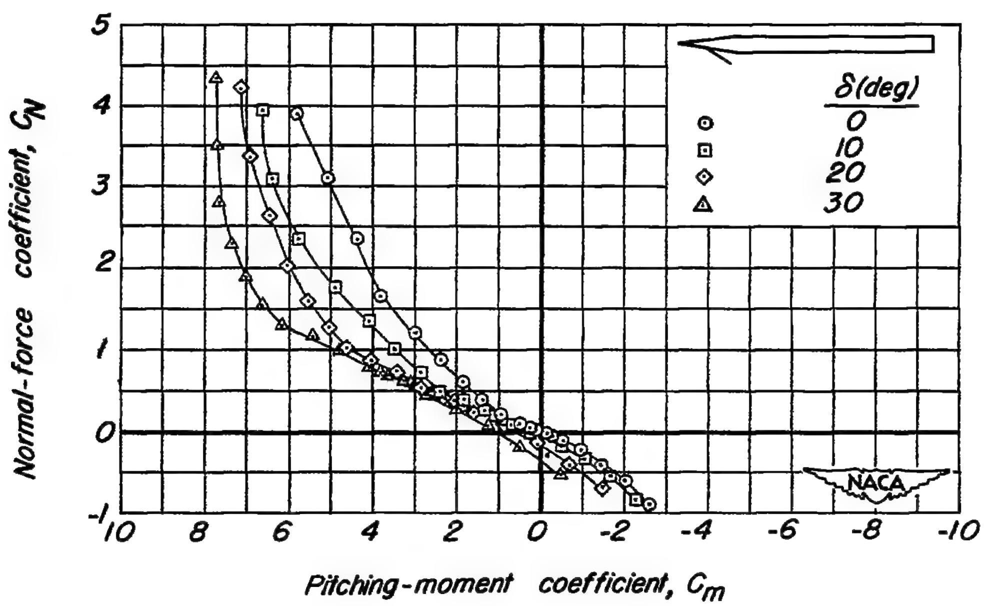
Figure 4.- Concluded.



(a) M=1.2

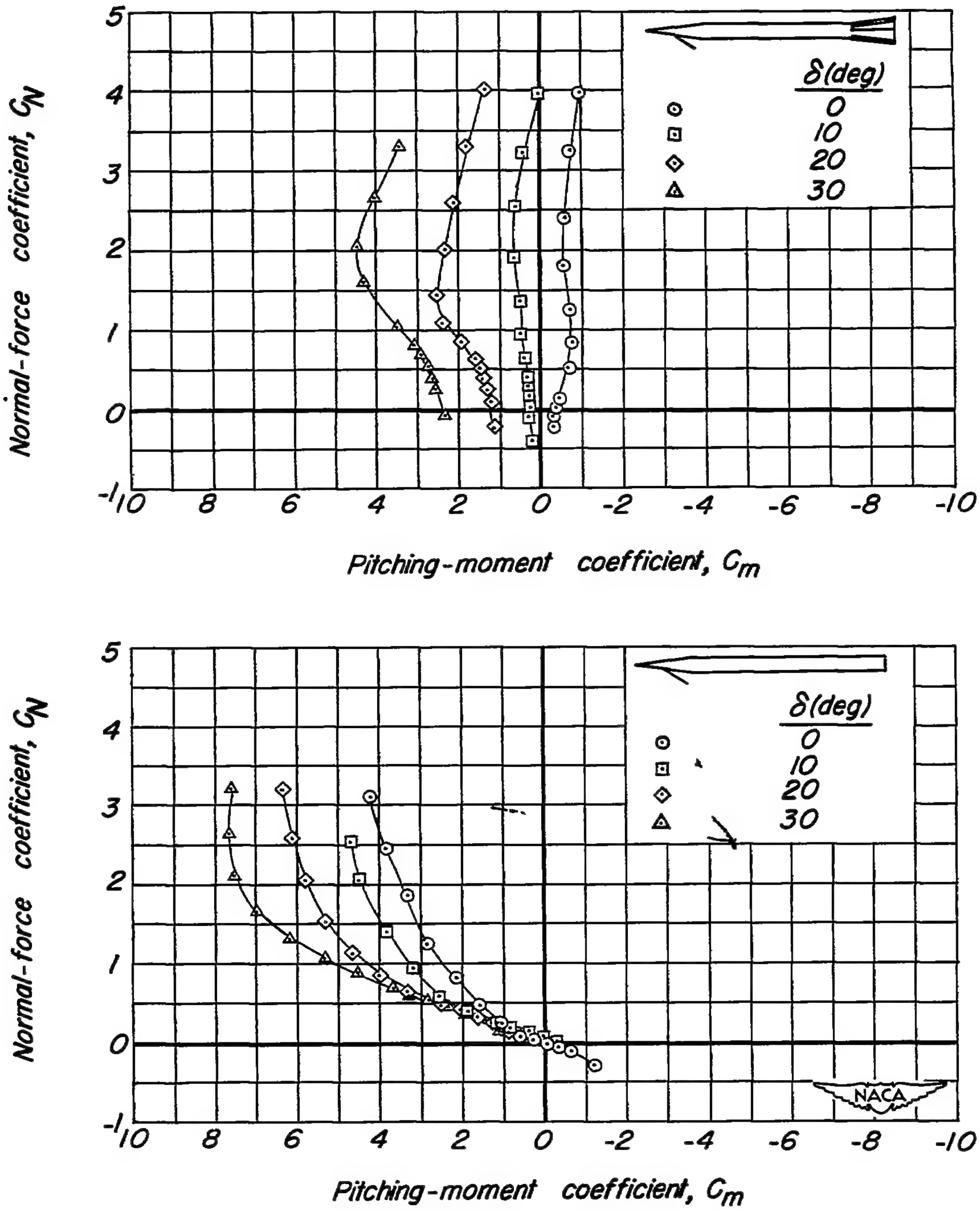
Figure 5.- Variation of pitching-moment coefficient with normal-force coefficient of the tail-on and tail-off configurations at various control deflections, δ.





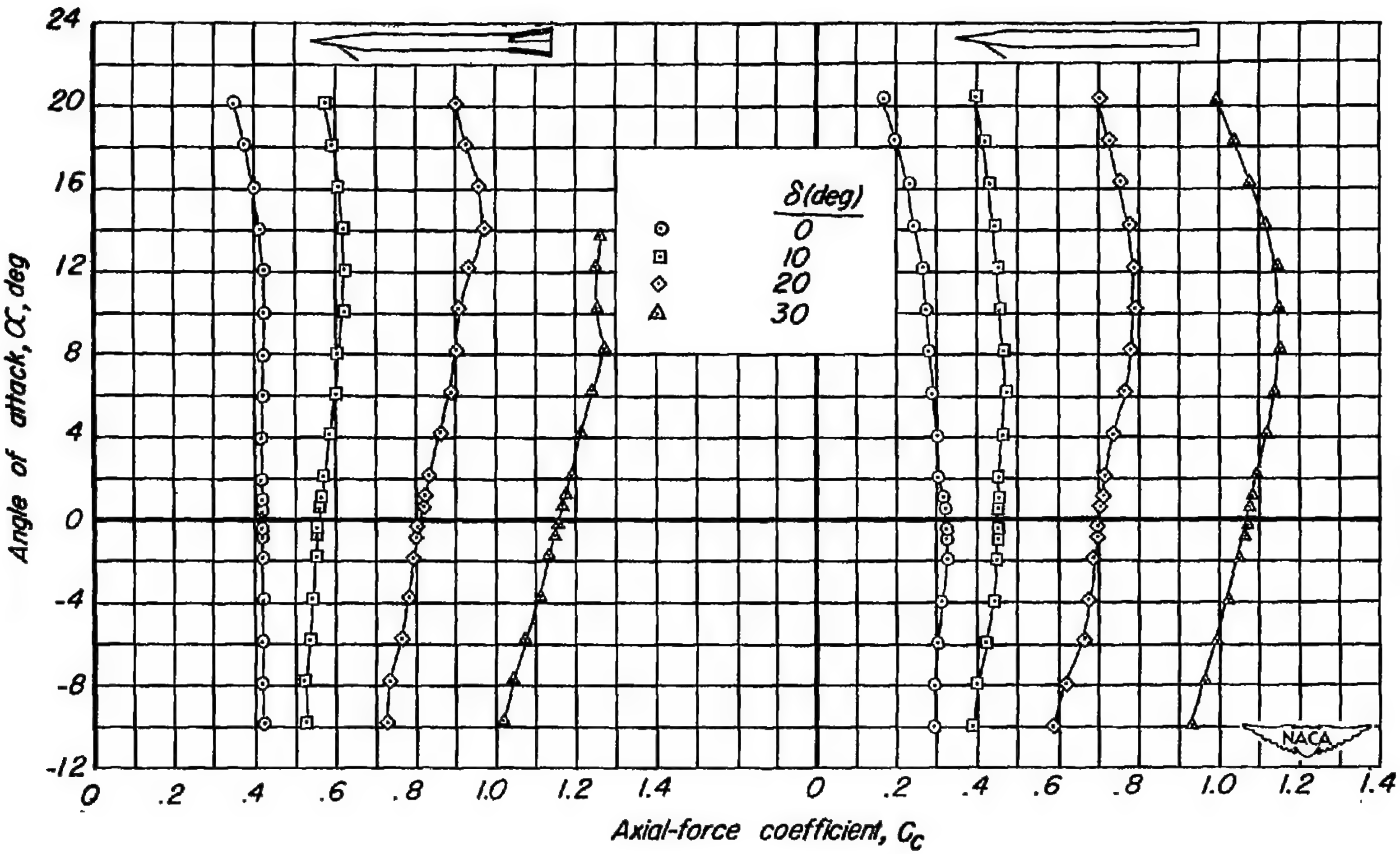
(b) M=1.9

Figure 5.- Continued.



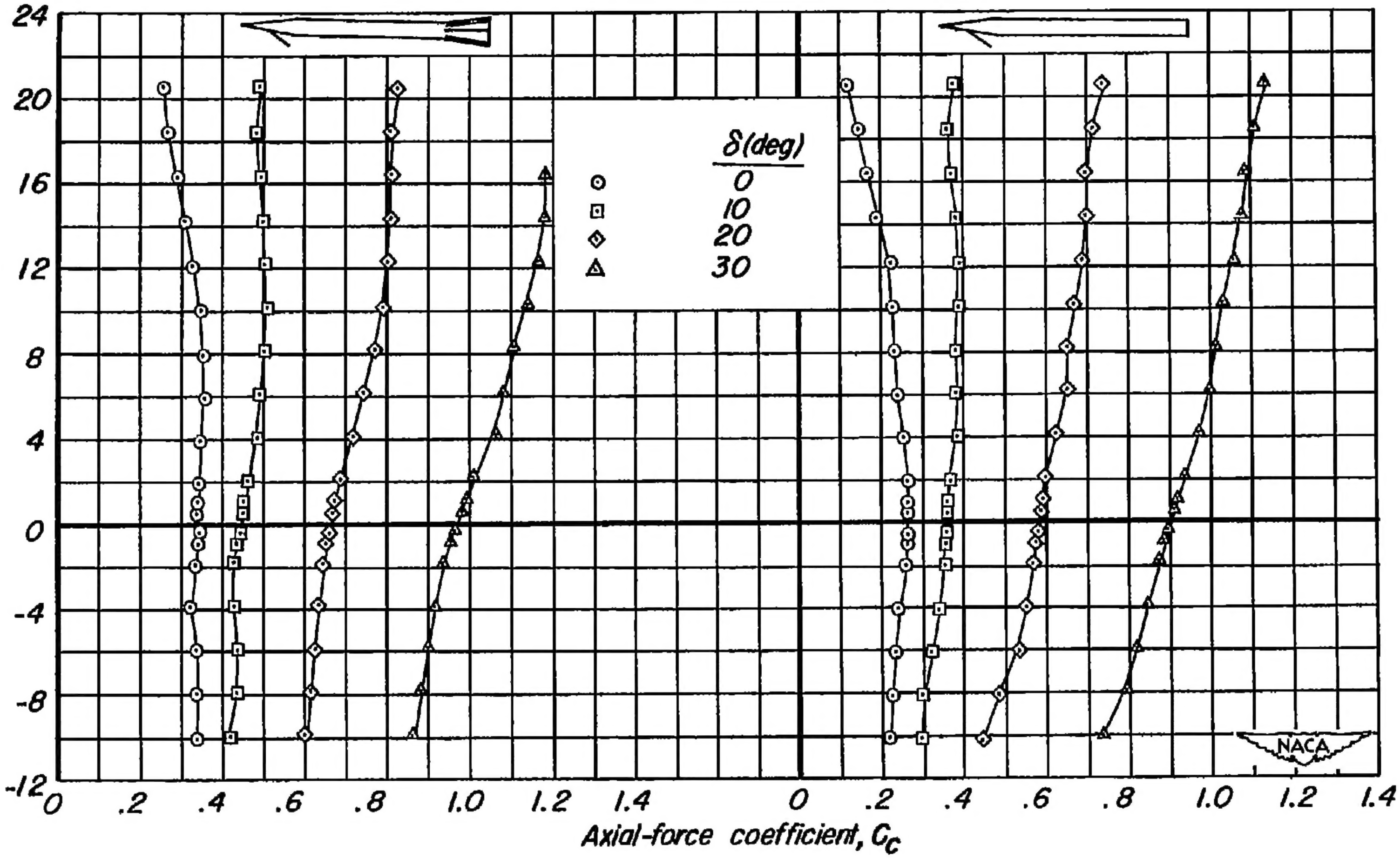
(c) M=2.94

Figure 5.- Concluded.



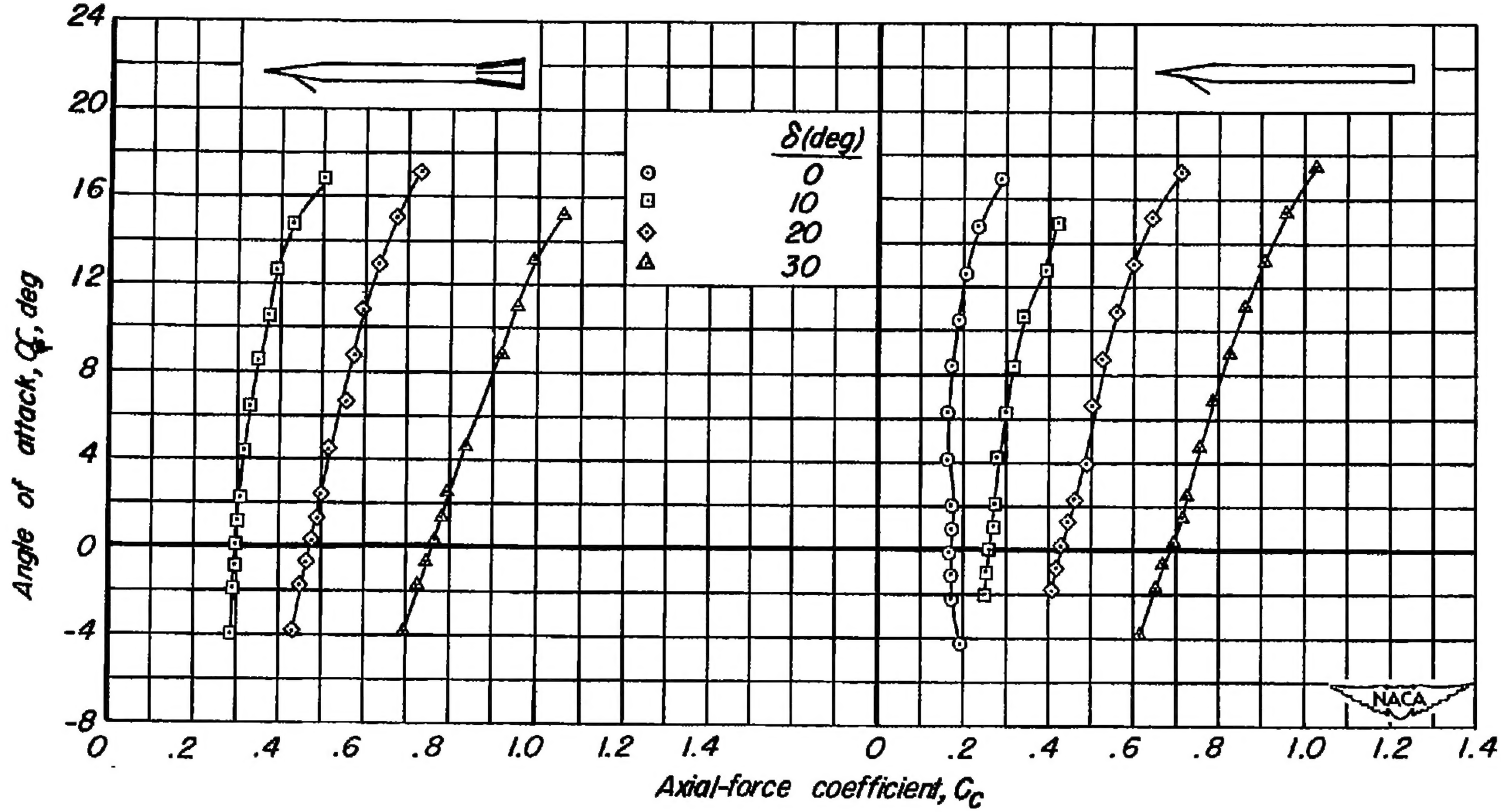
(a) M=1.2

Figure 6.- Variation of axial-force coefficient with angle-of-attack for the tail-on and tail-off configurations at various control deflections, δ.



(b) M=1.9

Figure 6.- Continued.



(c) M=2.94

Figure 6.- Concluded.

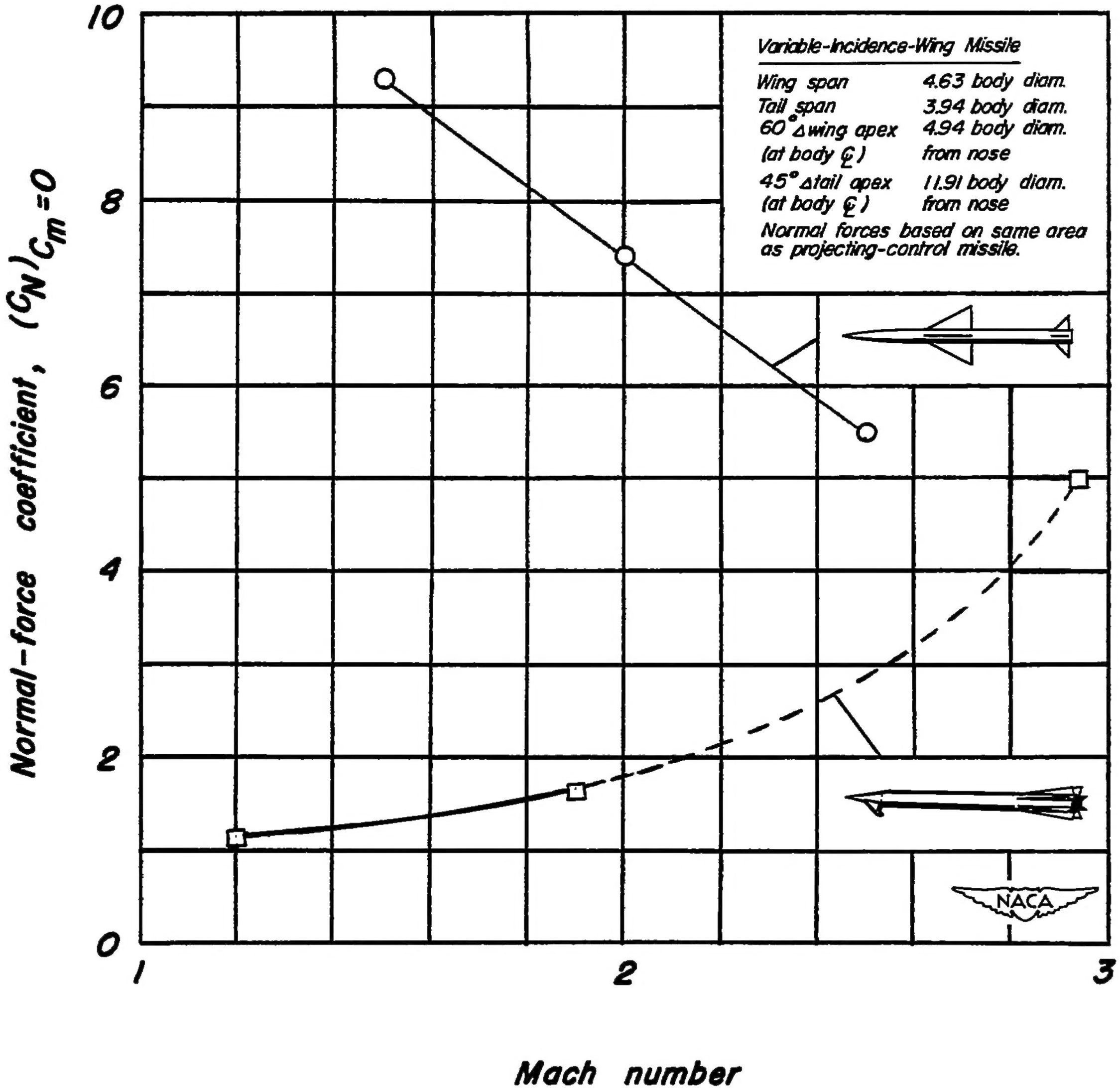


Figure 7. – Variation of trim normal-force coefficient with Mach number for a variable-incidence-wing missile and a projecting-control missile. ($\delta = 15°$)

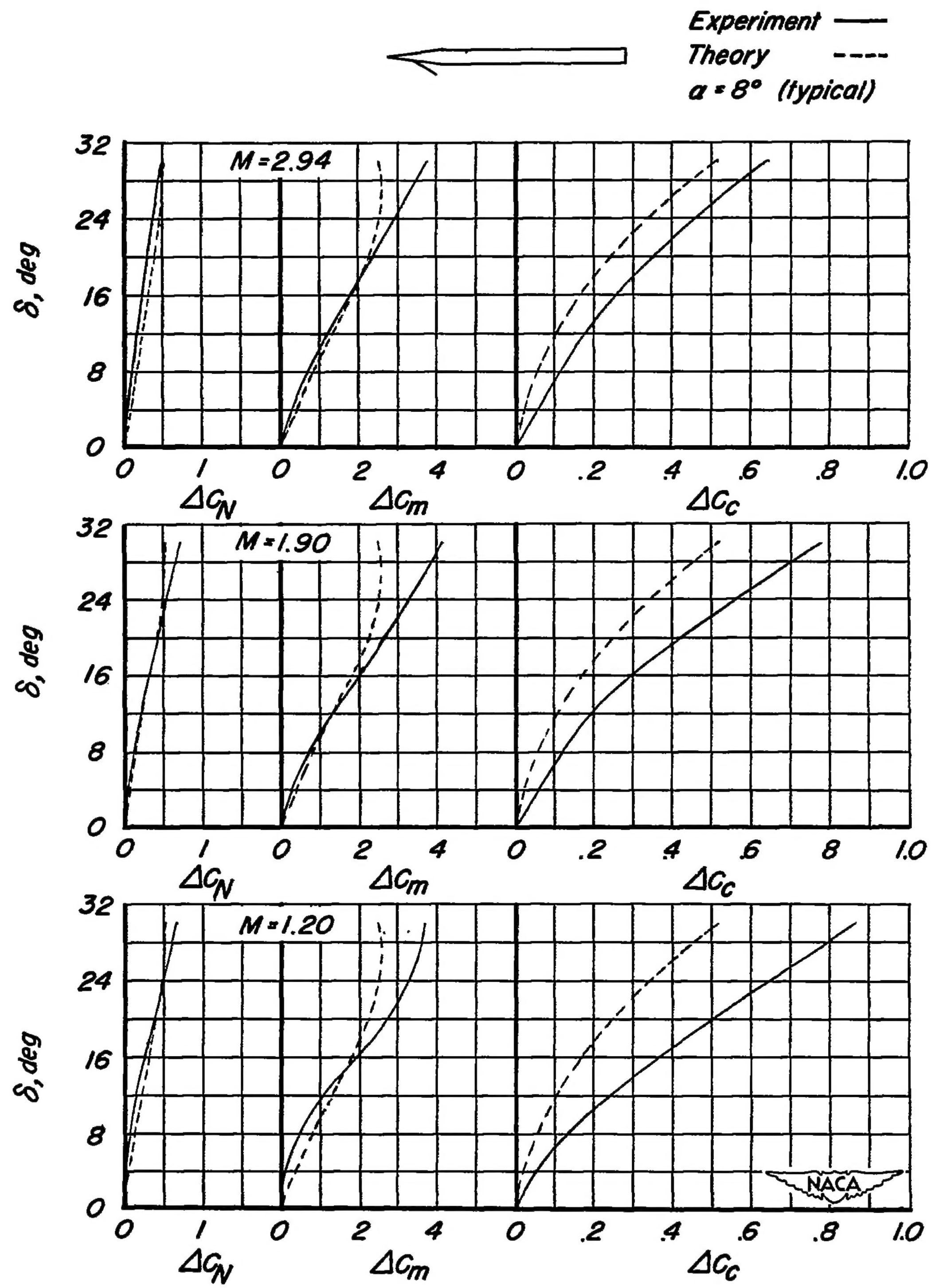


Figure 8.– Comparison of Newtonian impact theory and experiment for incremental force and moment coefficients.